



Europäisches Patentamt
European Patent Office
Office européen des brevets

②



① Publication number:

0 411 678 A1

③ EUROPEAN PATENT APPLICATION

② Application number: 90118215.4

⑤ Int. Cl.⁵ C12N 15/16, C12P 21/02,
C12N 5/10, C07K 13/00

② Date of filing: 03.12.85

This application was filed on 21.09.1990 as a
divisional application to the application
mentioned under INID code 80.

⑤ Priority: 04.12.84 US 677613
03.01.85 US 686522
22.01.85 US 683258

④ Date of publication of application:
05.02.91 Bulletin 91/05

⑥ Publication number of the earlier application in
accordance with Art.76 EPC: 0 205 664

④ Designated Contracting States:
AT BE CH DE FR GB IT LI LU NL SE

⑦ Applicant: GENETICS INSTITUTE, INC.
87 Cambridge Park Drive
Cambridge, MA 02140(US)

⑦ Inventor: Fritsch, Edward
115 North Brand Road
Concord, Massachusetts 01742(US)
Inventor: Jacobs, Kenneth
151 Beaumont Ave.
Newton, Massachusetts 02160(US)
Inventor: Hewick, Rodney M.
16 Woodcliffe Road
Lexington, Massachusetts 02173(US)

⑦ Representative: Huber, Bernhard, Dipl.-Chem.
et al
Mühlstrasse 22 Postfach 860 820
D-8000 München 86(DE)

④ Method for the production of erythropoietin.

④ The invention refers to recombinant DNA plasmid vector containing cDNA encoding human EPO of clone
lambda HEPOL13 (ATCC 40153) and mammalian cell transformed with this vector or with a plasmid which
contains the entire bovine papilloma virus DNA and the cDNA sequence of Table 3 coding for human EPO are
which useful in the preparation of recombinant human erythropoietin which is characterized by the presence of
O-linked glycosylation.

EP 0 411 678 A1

METHOD FOR THE PRODUCTION OF ERYTHROPOIETIN

FIELD OF THE INVENTION

The present invention is directed to cloned genes for human erythropoietin that provide surprisingly
high expression levels, to the expression of said genes and to the in vitro production of active human
erythropoietin.

BACKGROUND OF THE INVENTION

Erythropoietin (hereinafter EPO) is a circulating glycoprotein, which stimulates erythrocyte formation in
higher organisms. See, Carnot et al, Compt. Rend., 143:384 (1906). As such, EPO is sometimes referred to
as an erythropoiesis stimulating factor.

The life of human erythrocytes is about 120 days. Thus, about 1/120 of the total erythrocytes are
destroyed daily in the reticulo-endothelial system. Concurrently, a relatively constant number of eryth-
rocytes are produced daily to maintain the level of erythrocytes at all times (Guyton, Textbook of Medical
Physiology, pp 58-60, W. B. Saunders Co., Philadelphia (1976)).

Erythrocytes are produced by the maturation and differentiation of the erythroblasts in bone marrow,
and EPO is a factor which acts on less differentiated cells and induces their differentiation to erythrocytes
(Guyton, supra).

EPO is a promising therapeutic agent for the clinical treatment of anemia or, in particular, renal anemia.
Unfortunately, the use of EPO is not yet common in practical therapy due to its low availability.

For EPO to be used as a therapeutic agent, consideration should be given to possible antigenicity
problems, and it is therefore preferable that EPO be prepared from a raw material of human origin. For
example, human blood or urine from patients suffering from aplastic anemia or like diseases who excrete
large amounts of EPO may be employed. These raw materials however, are in limited supply. See, for
example, White et al., Rec. Progr. Horm. Res., 16:219 (1980); Espada et al., Biochem. Med., 3:475 (1970);
Fisher, Pharmacol. Rev., 24:459 (1972) and Gordon, Vitam. Horm. (N.Y.) 31:105 (1973), the disclosures of
which are incorporated herein by reference.

The preparation of EPO products has generally been via the concentration and purification of urine from
patients exhibiting high EPO levels, such as those suffering from aplastic anemia and like diseases. See for
example, U.S. Patent Nos. 4,397,840; 4,303,650 and 3,865,801 the disclosures of which are incorporated
herein by reference. The limited supply of such urine is an obstacle to the practical use of EPO, and thus it
is highly desirable to prepare EPO products from the urine of healthy humans. A problem in the use of
urine from healthy humans is the low content of EPO therein in comparison with that from anemic patients.
In addition, the urine of healthy individuals contains certain inhibiting factors which act against
erythropoiesis in sufficiently high concentration so that a satisfactory therapeutic effect would be obtained
from EPO derived therefrom only following significant purification.

EPO can also be recovered from sheep blood plasma, and the separation of EPO from such blood
plasma has provided satisfactorily potent and stable water-soluble preparations. See, Goldwasser, Control
Cellular Dif. Develop., Part A, pp 487-494, Alan R. Liss, Inc., N.Y. (1981), which is incorporated herein by
reference. Sheep EPO would however, be expected to be antigenic in humans.

Thus, while EPO is a desirable therapeutic agent, conventional isolation and purification techniques,
used with natural supply sources, are inadequate for the mass production of this compound.

Sugimoto et al., in U.S. Patent No. 4,377,513 describe one method for the mass production of EPO
comprising the in vivo multiplications of human lymphoblastoid cells, including Namalwa, BALL-1, NALL-1
TALL-1 and JBL.

The reported production by others of EPO using genetic engineering techniques had appeared in the
trade literature. However, neither an enabling disclosure nor the chemical nature of the product has yet
been published. In contrast, the present application provides an enabling disclosure for the mass production
of proteins displaying the biological properties of proteins displaying the biological properties of human
EPO. It is also possible by such techniques to produce proteins which may chemically differ from authentic
human EPO, yet manifest similar (and in some cases improved) properties. For convenience all such
proteins displaying the biological properties of human EPO may be referred to hereinafter as EPO whether
or not chemically identical thereto.

SUMMARY OF THE INVENTION

The present invention is directed to the cloning of a gene that expresses surprisingly high levels of human EPO, the expression thereof, and the mass production *in vitro* of active human EPO therefrom. Described also are suitable expression vectors for the production of EPO, expression cells, purification schemes and related processes.

As described in greater detail *infra*, EPO was obtained in partially purified form and was further purified to homogeneity and digested with trypsin to generate specific fragments. These fragments were purified and sequenced. EPO oligonucleotides were designed based on these sequences and synthesized. These oligos were used to screen a human genomic library from which was isolated an EPO gene.

The EPO gene was verified on the basis of its DNA sequence which matched many of the typical protein fragments sequenced. A piece of the genomic clone was then used to demonstrate by hybridization that EPO mRNA could be detected in human fetal (20. week old) mRNA. A human fetal liver cDNA library was prepared and screened. Three EPO cDNA clones were obtained (after screening >750,000 recombinants). Two of these clones were determined to be full length as judged by complete coding sequence and substantial 5'-prime and 3'-prime untranslated sequence. These cDNAs have been expressed in both SV-40 virus transformed monkey cells (the COS-1 cell line; Gluzman, Cell 23:175-182 (1981)) and Chinese hamster ovary cells (the CHO cell line; Urlaub, G. and Chasin, L. A. Proc. Natl. Acad. Sci USA 77:4218-4230 (1980)). The EPO produced from COS cells is biologically active *in vitro* and *in vivo*. The EPO produced from CHO cells is also biologically active *in vitro* and *in vivo*.

The EPO cDNA clone has an interesting open reading frame of 14-15 amino acids (aa) with initiator and terminator from 20 to 30 nucleotides (nt) upstream of the coding region. A representative sample of E. coli transfected with the cloned EPO gene has been deposited with the American Type Culture Collection, Rockville, Maryland, where it is available under Accession Number ATCC 40153.

BRIEF DESCRIPTION OF DRAWINGS AND TABLES

Table 1 is the base sequence of an 87 base pair exon of a human EPO gene;

Figure 1 illustrates the detection of EPO mRNA in human fetal liver mRNA;

Table 2 illustrates the amino acid sequence of an EPO protein deduced from the nucleotide sequence of lambda-HEPOFL13;

Table 3 illustrates the nucleotide sequence of the EPO cDNA in lambda-HEPOFL13 (shown schematically in Figure 2) and the amino acid sequence deduced therefrom;

Figure 3 illustrates the relative positions of DNA inserts of four independent human EPO genomic clones;

Figure 4 illustrates a map of the apparent intron and exon structure of the human EPO gene;

Table 4 illustrates a DNA sequence of the EPO gene illustrated in Figure 4B;

Figures 5A, 5B and 5C illustrate the construction of the vector p1023(B);

Figure 6 illustrates SDS polyacrylamide gel analysis of EPO produced in COS-1 cells compared with native EPO;

Table 5 illustrates the nucleotide and amino acid sequence of the EPO clone, lambda-HEPOFL6;

Table 6 illustrates the nucleotide and amino acid sequence of the EPO clone, lambda-HEPOFL8;

Table 7 illustrates the nucleotide and amino acid sequence of the EPO clone lambda-HEPOFL13;

Figure 7 is a schematic illustration of the plasmid pR1-4; and

Figure 8 is a schematic illustration of the plasmid p8BPV-MMTvec(342-12).

DETAILED DESCRIPTION

The present invention is directed to the cloning of EPO genes and to the production of EPO by the *in vitro* expression of these genes.

The patent and scientific literature is replete with processes reportedly useful for the production of recombinant products. Generally, these techniques involve the isolation or synthesis of a desired gene sequence, and the expression of that sequence in either a prokaryotic or eucaryotic cell, using techniques commonly available to the skilled artisan. Once a given gene has been isolated, purified and inserted into a transfer vector (i.e., cloned), its availability in substantial quantity is assured. The vector with its cloned gene is transferred to a suitable micro-organism or cell line, for example, bacteria, yeast, mammalian cells such

as, COS-1 (monkey kidney), CHO (Chinese hamster ovary), insect cell lines, and the like, wherein the vector replicates as the microorganism or cell line proliferates and from which the vector can be isolated by conventional means. Thus there is provided a continuously renewable source of the gene for further manipulations, modifications and transfers to other vectors or other loci within the same vector.

Expression may often be obtained by transferring the cloned gene, in proper orientation and reading frame, into an appropriate site in a transfer vector such that translational read-through from a prokaryotic or eucaryotic gene results in synthesis of a protein precursor comprising the amino acid sequence coded by the cloned gene linked to Met or an amino-terminal sequence from the prokaryotic or eucaryotic gene. In other cases, the signals for translation initiation can be supplied by a suitable genomic fragment of the cloned gene. A variety of specific protein cleavage techniques may be used to cleave the protein precursor, if produced, at a desired point so as to release the desired amino acid sequence, which may then be purified by conventional means. In some cases, the protein containing the desired amino acid sequence is produced without the need for specific cleavage techniques and may also be released from the cells into the extracellular growth medium.

Isolation of a Genomic Clone of Human EPO

Human EPO was purified to homogeneity from the urine of patients afflicted with aplastic anemia as described *infra*. Complete digestion of this purified EPO with the protease trypsin, yielded fragments which were separated by reverse phase high performance liquid chromatography, recovered from gradient fractions, and subjected to micro-sequence analysis. The sequences of the tryptic fragments are underlined in Tables 2 and 3 and are discussed in more detail *infra*. Two of the amino acid sequences, Val-Asn-Phe-Tyr-Ile-Trp-Lys and Val-Tyr-Ser-Asn-Phe-Leu-His, were chosen for the design of oligonucleotide probes (resulting in an oligonucleotide pool 17nt long and 32-fold degenerate, and an oligonucleotide pool 18nt long and 128-fold degenerate, from the former tryptic fragment, as well as two pools 14nt long, each 48-fold degenerate, from the latter tryptic fragment, respectively). The 32-fold degenerate 17mer pool was used to screen a human genomic DNA library in a Chi4A vector (22) using a modification of the Woo and O'Malley *in situ* amplification procedure (47) to prepare the filters for screening.

As used herein, arabic numbers in parentheses, (1) through (61), are used to refer to publications that are listed in numerical order at the end of this specification.

Phage hybridizing to the 17mer were picked, pooled in small groups and probed with the 14mer and 18mer pools. Phage hybridizing to the 17mer, 18mer and 14mer pools were plaque purified and fragments were subcloned into M13 vectors for sequencing by the dideoxy chain termination method of

TABLE 2														
-27-														
MET														
VAL	TRP	LEU	TRP	LEU	LEU	LEU	LEU	LEU	LEU	LEU	LEU	LEU	GLY	PRO
1	ALA	TRP	LEU	TRP	LEU	LEU	LEU	LEU	LEU	LEU	LEU	LEU	GLY	PRO
10	ALA	PRO	PRO	ARG	LEU	ILE	CYS	ASP	SER	ARG	VAL	LEU	GLY	PRO
20	ALA	PRO	PRO	ARG	LEU	ILE	CYS	ASP	SER	ARG	VAL	LEU	GLY	PRO
30	ALA	PRO	PRO	ARG	LEU	ILE	CYS	ASP	SER	ARG	VAL	LEU	GLY	PRO
40	ALA	PRO	PRO	ARG	LEU	ILE	CYS	ASP	SER	ARG	VAL	LEU	GLY	PRO
50	ALA	PRO	PRO	ARG	LEU	ILE	CYS	ASP	SER	ARG	VAL	LEU	GLY	PRO
60	ALA	PRO	PRO	ARG	LEU	ILE	CYS	ASP	SER	ARG	VAL	LEU	GLY	PRO

EP 0 411 678 A1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466
---	---	---	---	---	---	---	---	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

EPO genomic clones has been obtained by sequencing additional exons containing other tryptic fragment coding information.

Isolation of EPO cDNA Clones

Northern Analysis (58) of human fetal (20 week old) liver mRNA was conducted using a 95nt single-stranded probe prepared from an M13 clone containing a portion of the 87bp exon described in Table 1. As illustrated in Figure 1, a strong signal could be detected in fetal liver mRNA. The precise identification of this band as EPO mRNA was achieved by using the same probe to screen a bacteriophage lambda cDNA library of the fetal liver mRNA (25). Several hybridizing clones were obtained at a frequency of approximately 1 positive per 250,000 recombinants screened. The complete nucleotide and deduced amino acid sequences for these clones (lambda-HEPOFL13 and lambda-HEPOFL18) are shown in Tables 5 and 6. The EPO coding information is contained within 594nt in the 5-prime half of the cDNA, including a very hydrophobic 27 amino acid leader and the 168 amino acid mature protein.

The identification of the N-terminus of the mature protein was based on the N-terminal sequence of the protein secreted in the urine of persons with aplastic anemia as illustrated herein (Table 1), and as published by Goldwasser (26), Sue and Sytkowski (27), and by Yangawa (21). Whether this N-terminus (Ala-Pro-Arg-) represents the actual N-terminus found on EPO in circulation or whether some cleavage occurs in the kidney or urine is presently unknown.

The amino acid sequences which are underlined in Tables 2 and 3 indicate those tryptic fragments or the portion of the N-terminus for which protein sequence information was obtained. The deduced amino acid sequence agrees precisely with the tryptic fragments which have been sequenced, confirming that the isolated gene encodes human EPO.

Structure and Sequence of the Human EPO Gene

The relative positions of the DNA inserts of four independent human EPO genomic clones are shown in Figure 3. Hybridization analysis of these cloned DNAs with oligonucleotide probes and with various probes prepared from the two classes of EPO cDNA clones positioned the EPO gene within the approximately 3.3 kb region shown by the darkened line in Figure 3. Complete sequence analysis of this region (see Example 4) and comparison with the cDNA clones, resulted in the map of the intron and exon structure of the EPO gene shown in Figure 4. The EPO gene is divided into 5 exons. Part of exon I, all of exons II, III and IV, and part of exon V, contain the protein coding information. The remainder of exons I and V encode the 5-prime and the 3-prime untranslated sequences respectively.

Transient Expression of EPO in COS Cells

To demonstrate that biologically active EPO could be expressed in an in vitro cell culture system, COS cell expression studies were conducted (59). The vector used for the transient studies, p91023(E), is described in Example 5. This vector contains the adenovirus major late promoter, an SV40 polyadenylation sequence, an SV40 origin of replication, SV40 enhancer, and the adenovirus VA gene. The cDNA insert in lambda-HEPOFL13 (see Table 6) was inserted into the p91023(E) vector, downstream of the adenovirus major late promoter. This new vector is identified as PPTFL13.

Twenty four hours after transfection of this construct into the M8 strain of COS-1 cells (Horowitz et al. J. Mol. Appl. Genet. 2:147-149 (1983)), the cells were washed, changed to serum free media, and the cells were harvested 48 hrs. later. The level of release of EPO into the culture supernatant was then examined using a quantitative radioimmunoassay for EPO (55). As shown in Table 8, (Example 6) immunologically reactive EPO was expressed. The biological activity of the EPO produced from COS-1 cells was also examined. In a separate experiment, the vector containing EPO cDNA from lambda-HEPOFL13 was transfected into COS-1 cells and media harvested as described supra. EPO in the media was then quantified by the ester of two in vitro biological assays, ³H-thymidine and CFUE (12, 29), and by either of two in vivo assays, hypoxic mouse and starved rat (30, 31) (see Table 9, Example 7). These results demonstrate that biologically active EPO is produced in COS-1 cells. By Western blotting, using a polyclonal anti-EPO antibody, the EPO produced by COS cells has a mobility on SDS-polyacrylamide gels which is identical to that of native EPO prepared from human urine (Example 8). Thus, the extent of

glycosylation of COS-1 produced EPO may be similar to that of native EPO.

Different vectors containing other promoters can also be used in COS cells or in other mammalian or eukaryotic cells. Examples of such other promoters useful in the practice of this invention include SV40 early and late promoters, the mouse metallothionein gene promoter, the promoter found in the long terminal repeats of avian or mammalian retroviruses, the baculovirus polyhedron gene promoter and others. Examples of other cell types useful in the practice of this invention include E. coli, yeast, mammalian cells such as CHO (Chinese hamster ovary), C127 (monkey epithelium), 3T3 (mouse fibroblast) CV-1 (African green monkey kidney), and the insect cells such as those from *Spodoptera frugiperda* and *Drosophila melanogaster*. These alternate promoters and/or cell types may enable regulation of the timing or level of EPO expression, producing a cell-specific type of EPO, or the growth of large quantities of EPO producing cells under less expensive, more easily controlled conditions.

An expression system which retains the benefits of mammalian expression but requires less time to produce a high-level expression cell line is composed of an insect cell line and a DNA virus which reproduces in this cell line. The virus is a nuclear polyhedrosis virus. It has a double-stranded circular DNA genome of 128 kb. The nucleocapsid is rod-shaped and found packaged in two forms, the non-occluded form, a membrane budded virus and an occluded form, packaged in a protein crystal in the infected cell nucleus. These viruses can be routinely propagated in *in vitro* insect cell culture and are amenable to all routine animal virological methods. The cell culture media is typically a nutrient salt solution and 10% fetal calf serum.

In vitro, virus growth is initiated when a non-occluded virus (NOV) enter a cell and moves to the nucleus where it replicates. Replication is nuclear. During the initial phase (8-18 hrs. post-infection) of viral application, nucleocapsids are assembled in the nucleus and subsequently bud through the plasma membrane as NOVs, spreading the infection through the cell culture. In addition, some of the nucleocapsids subsequently (18+ hrs. post-infection) remain in the nucleus and are occluded in a protein matrix, known as the polyhedral inclusion body (PIB). This form is not infectious in cell culture. The matrix is composed of a protein known as polyhedrin, MW 33 kd. Each PIB is approximately 1 mm in diameter, and there can be as many as 100 PIBs per nucleus. There is clearly a great deal of polyhedrin produced late in the infection cycle, as much as 25% of total cellular protein.

Because the PIB plays no role in the *in vitro* replication cycle, the polyhedrin gene can be deleted from the virus chromosome with no effect on *in vitro* viability. In using the virus as an expression vector, we have replaced the polyhedrin gene coding region with the foreign DNA to be expressed, placing it under the control of the polyhedrin promoter. This results in a non-PIB forming virus phenotype.

This system has been utilized by several researchers the most noted being Pennock et al. and Smith et al. Pennock et al. (Gregory D. Pennock, Charles Shoemaker, and Lois K. Miller, *Molecular and Cell Biology* 3:34, p. 359-408) have reported on the high level expression of a bacterial protein, B-galactosidase, when placed under the control of the polyhedrin promoter.

Another nuclear polyhedrosis virus-derived expression vector has been presented by Smith et al. (Gale E. Smith, Max D. Summers and M. J. Fraser, *Molecular and Cell Biology*, May 16, 1983, pp. 2156-2165). They have demonstrated the effectiveness of their vector through the expression of human B-interferon. The synthesized product was found to be glycosylated and secreted from insect cells, as would be expected. In Example 14, modifications to the plasmid containing the Autographa californica nuclear polyhedrosis virus (AcNPV) polyhedron gene are described which allow the easy insertion of the EPO gene into the plasmid so that it may be under the transcriptional control of the polyhedrin promoter. The resulting DNA is co-transfected with intact chromosome DNA from wild type AcNPV into insect cells. A genetic recombination event results in the replacement of the AcNPV polyhedrin gene region with the DNA from the plasmid. The resulting recombinant virus can be identified amongst the viral progeny by its possession of the DNA sequences of the EPO gene. This recombinant virus, upon reinfection of insect cells is expected to produce EPO.

Examples of EPO expression in CHO, C127 and 3T3, and insect cells are given in Examples 10 and 11 (CHO), 13 (C127 and 3T3) and 14 (insect cells).

Recombinant EPO produced in CHO cells as in Example 11 was purified by conventional column chromatographic methods. The relative amounts of sugars present in the glycoprotein were analyzed by two independent methods [(i) Reinhold, *Methods in Enzymol.* 50:244-249 (Methanolysis) and (ii) Takenoto, H. et al., *Anal. Biochem.* 145:245 (1985) (pyridyl amination, together with independent sialic acid determination)]. The results obtained by each of these methods were in excellent agreement. Several determinations were thus made, yielding the following average values wherein N-acetylglucosamine is, for comparative purposes, given a value of 1:

Sugar	Relative molar level
N-Acetylglucosamine	1
Hexoses:	1.4
Galactose	0.9
Mannose	0.5
N-Acetylneuraminic acid	1
Fucose	0.2
N-Acetylglucosamine	0.1

It is noteworthy that significant levels of fucose and N-acetylglucosamine were reproducibly observed using both independent methods of sugar analysis. The presence of N-acetylglucosamine indicates the presence of O-linked glycosylation on the protein. The presence of O-linked glycosylation was further indicated by SDS-PAGE analysis of the glycoprotein following digestion of the glycoprotein with various combinations of glycosidic enzymes. In particular, following enzymatic removal of all N-linked carbohydrate on the glycoproteins using the enzyme peptide endo F N-glycosidase, the molecular weight of the protein was further reduced upon subsequent digestion with neuraminidase, as determined by SDS-PAGE analysis.

In vitro biological activity of the purified recombinant EPO was assayed by the method of G. Krystal, *Exp. Hematol.* 11:849 (1983) (spleen cell proliferation bioassay) with protein determinations calculated based upon amino acid compositional data. Upon multiple determinations, the *in vitro* specific activity of the purified recombinant EPO was calculated to be greater than 200,000 units/mg protein. The average value was in the range of about 275,000 - 300,000 units/mg protein. Moreover, values higher than 300,000 have also been observed. The *in vivo* polycythemic mouse assay, Kazal and Erslev, *Am. Clinical Lab. Sci.*, Vol. B, p. 91 (1976) *in vitro* activity ratios observed for the recombinant material was in the range of 0.7 - 1.3.

It is interesting to compare the glycoprotein characterization presented above with the characterization for a recombinant CHO-produced EPO material previously reported in International Patent Application Publication No. WO 85/02610 (published 20 June 1985). The corresponding comparative sugar analysis described on page 65 of that application reported a value of zero for fucose and for N-acetylglucosamine and a hexoses:N-acetylglucosamine ratio of 15.08:1. The absence of N-acetylglucosamine indicates the absence of O-linked glycosylation in the previously reported glycoprotein. In contrast to that material, the recombinant CHO-produced EPO of this invention which is characterized above contains significant and reproducibly observable amounts of both fucose and N-acetylglucosamine, contains less than one-tenth the relative amount of hexoses and is characterized by the presence of O-linked glycosylation. Furthermore, the high specific activity of the above-described CHO-derived recombinant EPO of this invention may be directly related to its characteristic glycosylation pattern.

The biologically active EPO produced by the prokaryotic or eucaryotic expression of the cloned EPO genes of the present invention can be used for the *in vivo* treatment of mammalian species by physicians and/or veterinarians. The amount of active ingredient will, of course, depend upon the severity of the condition being treated, the route of administration chosen, and the specific activity of the active EPO, and ultimately will be decided by the attending physician or veterinarian. Such amount of active EPO was determined by the attending physician is also referred to herein as an "EPO treatment effective" amount. For example, in the treatment of induced hypoproliferative anemia associated with chronic renal failure in sheep, an effective daily amount of EPO was found to be 10 units/kg for from 15 to 40 days. See Eschbach et al., *J. Clin. Invest.*, 74:434 (1984).

The active EPO may be administered by any route appropriate to the condition being treated. Preferably, the EPO is injected into the bloodstream of the mammal being treated. It will be readily appreciated by those skilled in the art that the preferred route will vary with the condition being treated.

While it is possible for the active EPO to be administered as the pure or substantially pure compound, it is preferable to present it as a pharmaceutical formulation or preparation.

The formulations of the present invention, both for veterinary and for human use, comprise an active EPO protein, as above described, together with one or more pharmaceutically acceptable carriers thereof and optionally other therapeutic ingredients. The carrier(s) must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof. Desirably the formulation should not include oxidizing agents and other substances with which peptides are known to be incompatible. The formulations may conveniently be presented in unit dosage form and may be prepared by any of the methods well known in the art of pharmacy. All methods include the step of

bringing into association the active ingredient with the carrier which constitutes one or more accessory ingredients. In general, the formulations are prepared by uniformly and intimately bringing into association the active ingredient with liquid carriers or finely divided solid carriers or both, and then, if necessary, shaping the product into the desired formulation.

Formulations suitable for parenteral administration conveniently comprise sterile aqueous solutions of the active ingredient with solutions which are preferably isotonic with the blood of the recipient. Such formulations may be conveniently prepared by dissolving solid active ingredient in water to produce an aqueous solution, and rendering said solution sterile may be presented in unit or multi-dose containers, for example sealed ampoules or vials.

EPO_hcDNA as used herein includes the mature EPO_hcDNA gene preceded by an ATG codon and EPO_hcDNA coding for allelic variations of EPO protein. One allele is illustrated in Tables 2 and 3. The EPO protein includes the 1-methionine derivative of EPO protein (Met-EPO) and allelic variations of EPO protein. The mature EPO protein illustrated by the sequence in Table 2 begins with the sequence Ala.Pro.Pro.Arg...the beginning of which is depicted by the number "1" in Table 2. The Met-EPO would begin with the sequence Met.Ala.Pro.Pro.Arg...

The following examples are provided to aid in the understanding of the present invention, the true scope of which is set forth in the appended claims. It is understood that modifications can be made in the procedures set forth, without departing from the spirit of the invention. All temperatures are expressed in degrees Celsius and are uncorrected. The symbol for micron or micro, e.g., microliter, micromole, etc., is "μ", e.g., μl, μm, etc.

EXAMPLES

Example 1: Isolation of a Genomic Clone of EPO

EPO was purified from the urine of patients with aplastic anemia essentially as described previously (Mytelle, et al., J. Biol. Chem., 252:5558 (1977)) except that the phenol treatment was eliminated and replaced by heat treatment at 80 deg. for 5 min. to inactivate neuraminidases. The final step in the purification was fractionation on a C-4 Vydac HPLC column (The Separations Group) using 0 to 85% acetonitrile gradient with 0.1% trifluoroacetic acid (TFA) over 100 minutes. The position of EPO in the gradient was determined by gel electrophoresis and N-terminal sequence analysis (21, 26, 27) of the major peaks. The EPO was eluted at approximately 53% acetonitrile and represented approximately 40% of the protein subjected to reverse phase - HPLC. Fractions containing EPO were evaporated to 100 μl, adjusted to pH 7.0 with ammonium bicarbonate digested to completion with 2% TPCK-treated trypsin (Worthington) for 18 hrs. at 37 deg. The tryptic digestion was then subjected to reverse phase HPLC as described above. The optical density at both 280 and 214 nm was monitored. Well separated peaks were evaporated to near dryness, and subjected directly to N-terminal amino acid sequence analysis (59) using an Applied Biosystems Model 480A gas phase sequencer. The sequences obtained are underlined in Tables 2 and 3. As described herein supra, two of these tryptic fragments were chosen for synthesis of oligonucleotide probes. From the sequence, Val-Asn-Phe-Tyr-Ala-Tyr-Lys (amino acids 48 through 52 in Tables 2 and 3), a 17mer of 32 fold degeneracy

TTCCANGCGTGAAGTT

and an 18mer of 128 fold degeneracy

CCANGCGTAGAAGTTNAC

were prepared. From the sequence, Val-Tyr-Ser-Asn-Phe-Leu-Arg (amino acids 144 through 150 in Tables 2 and 3), two pools of 14mers, each 32-fold degenerate

TACACCTAACTTCCT and TACACCTAACTTCCT

which differ at the first position of the leucine codon were prepared. The oligonucleotides were labelled at the 5-prime end with ³²P using polynucleotide kinase (New England Biolabs) and gamma ³²P-ATP (New England Nuclear). The specific activity of the oligonucleotides varied between 1000 and 3000 Ci/mole oligonucleotide. A human genomic DNA library in bacteriophage lambda (Lawn et al., 22) was screened using a modification of the in situ amplification procedure originally described by Wico et al., (47) (1978).

Approximately 3.5 x 10⁶ phage were plated at a density of 8000 phage per 150 mm petri dish (NZCYM media) and incubated at 37 deg. until the plaques were visible, but small (approximately 0.5 mm). After chilling at 4 deg. for 1 hr., duplicate replicas of the plaque patterns were transferred to nylon membranes

(New England Nuclear and incubated overnight at 37 deg. on fresh NZCYM plates. The filters were then deatured and neutralized by flooding for a 10 min. each on a thin film of 0.5N NaOH - 1M NaCl and 0.5M Tris (pH 8) - 1M NaCl respectively. Following vacuum baking at 80 deg. for 2 hrs., the filters were washed in 5 x SSC, 0.5% SDS for 1 hr. and the cellular debris on the filter surface was removed by gentle scraping with a wet tissue. This scrubbing reduced the background binding of the probe to the filters. The filters were then rinsed with H₂O and prehybridized for from 4 to 8 hrs. at 48 deg. in 3M tetramethylemmonium chloride, 10 mM NaPO₄ (pH 6.8), 5 x Denhardt's, 0.5% SDS and 10mM EDTA. The ³²P-labelled 17mer was then added at a concentration of 0.1 pmol/ml and hybridization was carried out at 48 deg. for 72 hrs. Following hybridization the filters were washed extensively in 2 x SSC (0.3M NaCl-0.03M Na citrate, pH 7) at a room temperature and then for 1 hr. in 3M TMACl - 10mM NaPO₄ (pH 6.8) at room temperature and from 5 to 15 min. at the hybridization temperature. Approximately 120 strong duplicate signals were detected following 2 day autoradiography with an intensifying screen. The positives were picked, grouped in pools of 8, replated and rescreened in triplicate using one-half of the 14mer pool on each of two filters and the 127mer on the third filter. The conditions and the 17mer for plating and hybridization were as described supra except that hybridization for the 14mer was at 37 deg. Following autoradiography, the probe was removed from the 17mer filter in 50% formamide for 20 min. at room temperature and the filter was rehybridized at 52 deg. with the 18mer probe. Two independent phage hybridized to all three probes. DNA from one of these phages (designated herein, lambda HEPOT1) was digested to completion with Sau3A and subcloned into M13 for DNA sequence analysis using the dideoxy chain termination method of Sanger and Coulson, (23) (1977). The nucleotide sequence and deduced amino acid sequence of the open reading frame coding for the EPO tryptic fragment (underlined region) are described herein. Intron sequences are given in lower case letters; exon sequences (87nt) are given in upper case. Sequences which agree with consensus splice acceptor (a) and donor (d) sites are underlined. (See Table 4.)

Example 2: Northern Analysis of Human Fetal Liver mRNA

5 μg of human fetal liver mRNA (prepared from a 20 week old fetal liver) and adult liver mRNA were

electro

TABLE 4 (CONT.)

[illegible]

TABLE 4

[illegible]

screening (Benton Davis, Science, 54) (1973) procedures. Three independent positive clones (designated herein, lambda-HEPOFLB (7350bp), lambda-HEPOFLB (700bp) and lambda-HEPOFLB (1400bp) were isolated following screening of 1×10^5 plaques. The entire insert of lambda-HEPOFLB13 and lambda-HEPOFLB were sequenced following subcloning into M13. (Tables 7 and 5, respectively). Only portions of lambda-HEPOFLB were sequenced and the remainder assumed to be identical to the other two clones. (Table 6). The 5-prime and 3-prime untranslated sequences are represented by lower case letters. The coding region is represented by upper case letters.

[illegible]

phoresed in a 0.8% agarose formaldehyde gel and transferred to nitrocellulose using the method of Derman et al., Cell, 23:731 (1981). A single-stranded probe was then prepared from an M13 template containing the insert illustrated in Table 1. The primer was a 20mer derived from the same tryptic fragment as the original 17mer probe. The probe was prepared as previously described by Anderson et al., PNAS, 50 (1984) except that, following digestion with SmaI (which produced the desired probe of 95nt length containing 74nt of coding sequence), the small fragment was purified from the M13 template by chromatography on a sepharose C14B column in 0.1N NaOH - 0.2M NaCl. The filler was hybridized to approximately 5×10^5 cpm of this probe for 12 hrs. at 68 deg., washed in $2 \times$ SSC at 68 deg. and exposed for 6 days with an intensifying screen. A single marker mRNA of 1200 nt (indicated by the arrow) was run in an adjacent lane. (Figure 1).

55 **Example 3: Fetal Liver cDNA**

A probe identical to that described in Example 2 was prepared and used to screen a fetal liver cDNA library prepared in the vector lambda-Ch21A (Toole et al., Nature, (25) (1984)) using standard plaque

[illegible]

100	Val	Ala	GCC	ATC	ACT
120	Ser	Ala	GCC	ATC	TCC
140	Lys	Arg	GCG	ATG	AAV
160	Pro	Asp	GAT	TTC	CCT
180	Gly	Leu	Arg	GCC	CTT
200	Leu	Val	Asn	TCT	TTC
220	Ser	Gln	Pro	TCC	CTC
240	Thr	Leu	Thr	ACC	ACT
260	Ala	Pro	Ala	GCT	CCA
280	Arg	Leu	Arg	TTC	CTC
300	Leu	Phe	Leu	CTC	CTC
320	Arg	Gly	Arg	GCA	CGG
340	Leu	Lys	Leu	CTC	CTC
360	Val	Lys	Leu	CTC	CTC
380	Thr	Thr	Ala	GCT	ACT
400	Asp	Thr	Ala	GCT	ACT
420	Thr	Thr	Ala	GCT	ACT
440	Val	Val	Val	CTG	CTG
460	Leu	Leu	Leu	CTG	CTG
480	Gln	Gln	Gln	CTG	CTG
500	Leu	Leu	Leu	CTG	CTG
520	Val	Val	Val	CTG	CTG
540	Leu	Leu	Leu	CTG	CTG
560	Gln	Gln	Gln	CTG	CTG
580	Leu	Leu	Leu	CTG	CTG
600	Val	Val	Val	CTG	CTG
620	Leu	Leu	Leu	CTG	CTG
640	Gln	Gln	Gln	CTG	CTG
660	Leu	Leu	Leu	CTG	CTG
680	Val	Val	Val	CTG	CTG
700	Leu	Leu	Leu	CTG	CTG
720	Gln	Gln	Gln	CTG	CTG
740	Leu	Leu	Leu	CTG	CTG
760	Val	Val	Val	CTG	CTG
780	Leu	Leu	Leu	CTG	CTG
800	Gln	Gln	Gln	CTG	CTG

TABLE 6 (CONT.)

100	Val	Ala	GCC	ATC	ACT
120	Ser	Ala	GCC	ATC	TCC
140	Lys	Arg	GCG	ATG	AAV
160	Pro	Asp	GAT	TTC	CCT
180	Gly	Leu	Arg	GCC	CTT
200	Leu	Val	Asn	TCT	TTC
220	Ser	Gln	Pro	TCC	CTC
240	Thr	Leu	Thr	ACC	ACT
260	Ala	Pro	Ala	GCT	CCA
280	Arg	Leu	Arg	TTC	CTC
300	Leu	Phe	Leu	CTC	CTC
320	Arg	Gly	Arg	GCA	CGG
340	Leu	Lys	Leu	CTC	CTC
360	Val	Lys	Leu	CTC	CTC
380	Thr	Thr	Ala	GCT	ACT
400	Asp	Thr	Ala	GCT	ACT
420	Thr	Thr	Ala	GCT	ACT
440	Val	Val	Val	CTG	CTG
460	Leu	Leu	Leu	CTG	CTG
480	Gln	Gln	Gln	CTG	CTG
500	Leu	Leu	Leu	CTG	CTG
520	Val	Val	Val	CTG	CTG
540	Leu	Leu	Leu	CTG	CTG
560	Gln	Gln	Gln	CTG	CTG
580	Leu	Leu	Leu	CTG	CTG
600	Val	Val	Val	CTG	CTG
620	Leu	Leu	Leu	CTG	CTG
640	Gln	Gln	Gln	CTG	CTG
660	Leu	Leu	Leu	CTG	CTG
680	Val	Val	Val	CTG	CTG
700	Leu	Leu	Leu	CTG	CTG
720	Gln	Gln	Gln	CTG	CTG
740	Leu	Leu	Leu	CTG	CTG
760	Val	Val	Val	CTG	CTG
780	Leu	Leu	Leu	CTG	CTG
800	Gln	Gln	Gln	CTG	CTG

sequence of certain tryptic fragments which could not be determined unambiguously. The cDNA clones lambda-HEPOFLB, lambda-HEPOFLB and lambda-HEPOFL13 have been deposited and are available from the American Type Culture Collection, Rockville, Maryland as Accession Numbers ATCC 40158, ATCC 40152 and ATCC 40153, respectively.

Example 4: Genomic Structure of the EPO Gene

The relative sizes and positions of four independent genomic clones (lambda-HEP01, 2, 3, and 6) from the *HaesII*/AluI library are illustrated by the overlapping lines in Figure 3. The thickened line indicates the position of the EPO gene. A scale (in Kb) and the positions of known restriction endonuclease cleavage sites are shown. The region containing the EPO gene was completely sequenced from both strands using directed exonuclease III generated series of deletions through this region. A schematic representation of five exons coding for EPO mRNAs is shown in Figure 4. The precise 5-prime boundary of exon I is presently unknown. The protein coding portion of the exons are darkened. The complete nucleotide sequence of the region is shown in Table 4. The known limits of each exon are delineated by the solid vertical bars. Genomic clones lambda-HEP01, lambda-HEP02, lambda-HEP03 and lambda HEP06 have been deposited and are available from the American Type Culture Collection, Rockville, Maryland as Accession Numbers ATCC 40154, ATCC 40155, ATCC 40150, and ATCC 40151, respectively.

Example 5: Construction of Vector p91023(b)

The transformation vector was pAd28SVPa(3) described by Kaufman et al., *Mol. Cell Biol.* 2:1304 (1982). The structure of this vector is shown in Fig. 5A. Briefly, this plasmid contains a mouse dihydrofolate reductase (DHFR) cDNA gene that is under transcriptional control of the adenovirus 2 (Ad2) major late promoter. A 5-prime splice site is indicated in the adenovirus DNA and a 3-prime splice site, derived from the immunoglobulin gene, is present between the Ad2 major late promoter and the DHFR coding sequence. The AdV40 early polyadenylation site is present downstream from the DHFR coding sequence. The procarcyclobutened section of pAd28SVPa(3) is from pSVcat (Meilon et al., *Cell*, 27: 279 (1981)) and does not contain the pBR322 sequences known to inhibit replication in mammalian cells (Lusky et al., *Nature*, 283: 79 (1981)).

pAD26SvpA(3) was converted to plasmid pCVSVL2 as illustrated in Fig. 5A. pAD26SvpA(3) was converted to plasmid pAD26SvpA(3)(d) by the deletion of one of the two PstI sites in pAD26SvpA(3). This was accomplished by a partial digestion with PstI using a deficiency of enzyme such that a subpopulation of linearized plasmids are obtained in which only one PstI site was cleaved, followed by treatment with Klenow, ligation to recircularize, and screening for deletion of the PstI site located 3-prime to the SV40 noncoding sequence.

The adenovirus tripartite leader and virus associated genes (VA genes) were inserted into pAdD26SvPA3(c)d) as illustrated in Fig. 5A. First, pAdD26SvPA3(c)d) was cleaved with PvuII to make a linear molecule opened within the 3-prime portion of the three elements comprising the tripartite leader. Then, pJAW 43 (Zain et al., Cell, 18: 651 (1979)) was digested with Xho 1, treated with Klenow, digested with PvuII, and the 140bp fragment containing the second part of the third leader was isolated by electrophoresis on an acrylamide gel (6% in Tris borate buffer; Maniatis et al., supra.). The 140bp fragment was then ligated to the PvuII digested pAdD26SvPA3(c)d). The ligation product was used to transform *E. coli* to tetracycline resistance and colonies were screened using the Grunstein-Hogness procedure employing a ³²P labelled probe hybridizing to the 140bp fragment. DNA was prepared from positively hybridizing colonies to test whether the PvuII site reconstructed was 5-prime or 3-prime of the inserted 140bp DNA specific to the second and third adenovirus late leaders. The correct orientation of the PvuII site is on the 5-prime side of the 140bp insert. This plasmid is designated ITPL in Fig. 5A.

The Ava II fragment of SV40 containing the SV40 enhancer sequence was obtained by digesting the SV40 DNA with Ava II, blunting the ends with the Klenow fragment of Pol I, ligating Xho 1 linkers to the ends of the DNA fragment, digesting with Xho 1, and isolating the fourth (gel) fragment by gel electrophoresis. This fragment was then ligated to Xho 1 cut pTPL, yielding the plasmid pCVSV2-TPL. The orientation of the SV40 DNA fragment in pCVSV2-TPL was such that the SV40 late promoter was in the same orientation as the adenovirus major late promoter.

To introduce the adenovirus associated (VA) genes into the pCVSVL2-TPL, first a plasmid pBR322 was constructed that contained the adenovirus type 2 Hind III B fragment. Adenovirus type 2 DNA was digested

with Hind III and the B fragment was isolated by gel electrophoresis. This fragment was inserted into pBR322 which had previously been digested with Hind III. After transformation of E. coli to ampicillin resistance, recombinants were screened for insertion of the Hind III B fragment and the inserted orientation was determined by restriction enzyme digestion. pBR322 - Ad Hind III B contains the adenovirus type 2 Hind III B fragment in the orientation depicted in Fig. 5B.

As illustrated in Fig. 5B, the VA genes are conveniently obtained from plasmid pBR322 - Ad Hind III B by digestion with Hpa I, adding EcoRI linkers and digestion with EcoRI, followed by recovery of the 1.4kb fragment. The fragment having EcoRI sticky ends is then ligated into the EcoRI site of PTL, previously digested with EcoRI. After transforming E. coli HB101 and selecting for tetracycline resistance, colonies were screened by filter hybridization to DNA specific for the VA genes. DNA was prepared from positively hybridizing clones and characterized by restriction endonuclease digestion. The resulting plasmid is designated p91023.

As illustrated in Fig. 5C, the two EcoRI sites in p91023 were removed by cutting p91023 to completion with EcoRI, generating two DNA fragments, one about 7kb and the other about 1.3kb. The latter fragment contained the VA genes. The ends of both fragments were filled in using the Klenow fragment of pol and the two fragments were then ligated together. A plasmid p91023(A), containing the VA genes and similar to p91023, but deleted for the two EcoRI sites, were identified by Grunstein-Hogness screening with the VA gene fragment, and by conventional restriction site analysis.

The single PstI site in p91023(A) was removed and replaced with an EcoRI site. p91023(a) was cut to completion with PstI and treated with the Klenow fragment of pol to generate flush ends. EcoRI linkers were ligated to the blunt PstI site of p91023(A). The linear p91023(A), with EcoRI linkers attached at the blunt PstI site was separated from unligated linkers and digested to completion with EcoRI, and religated. A plasmid, p91023(B) as depicted in Figure 5C was recovered, and identified as having a structure similar to p91023(A), but with an EcoRI site in place of the former PstI site. Plasmid p91023(B) has been deposited and is available from the American Type Culture Collection, Rockville, Maryland as Accession Number ATCC 39754.

Example 6:

The cDNA clones (lambda-EPOFLB and lambda-EPOFL13; Example 3) were inserted into the plasmid p91023(B) forming PPTFLB and PPTFL13, respectively. 8 ug of each of the purified DNA's was then used to transfect 5×10^6 COS cells using the DEAE-dextran method (Intra). After 12 hrs., the cells were washed and treated with Chloroquin (0.1mm) for 2 hrs., washed again, and exposed to 10 ml media containing 10% fetal calf serum for 24 hrs. The media was changed to 4 ml serum free media and harvested 48 hrs. later.

Production of immunologically active EPO was quantified by a radioimmunoassay as described by Sherwood and Goldwasser (55). The antibody was provided by Dr. Judith Sherwood. The iodinated tracer was prepared from the homogeneous EPO described in Example 1. The sensitivity of the assay is approximately 1ng/ml. The results are shown below in Table 8.

TABLE 8

VECTOR	LEVEL OF EPO RELEASED INTO THE MEDIA (ng/ml)
pPTFL13	330
pPTFLB	31

PPTFL13 has been deposited and is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 39890.

Example 7

EPO cDNA (lambda-EPOFL13) was inserted into the p91023(B) vector and was transfected into COS-1 cells and harvested as described above (Example 6) except that the chloroquin treatment was omitted. In vitro biologically active EPO was measured using either a colony forming assay with mouse fetal liver

cells as a source of CFU-E or a 3H-thymidine uptake assay using spleen cells from phenylhydrazine injected mice. The sensitivities of these assays are approximately 25 mUnits/ml. In vitro biologically active EPO was measured using either the hypoxic mouse or starved rat method. The sensitivity of these assays is approximately 100 U/ml. No activity was detected in either assay from mock condition media. The results of EPO expressed by clone EPOFL13 are shown below in Table 9 wherein the activities reported are expressed in units/ml, using a commercial, quantified EPO (Toyobo, Inc.) as a standard.

TABLE 9

EPO Excreted from COS Cells Transfected with Type I EPO cDNA		
Assay	Activity	
RIA	100 ng/ml	
CFU-E	2.05 U/ml	
3H-Thy hypoxic mouse	3.118 U/ml	
starved rat	1 U/ml	
	2 U/ml	

Example 8: SDS Polyacrylamide Gel Analysis of EPO from COS Cells

180 ng of EPO released into the media of COS cells transfected with EPO (lambda-EPOFL13) cDNA in the vector 91023(B) (supra) was electrophoresed on a 10% SDS Laemmli polyacrylamide gel and electrotransferred to nitrocellulose paper (Towbin et al., Proc. Natl. Acad. Sci. USA 76:4350 (1979)). The filter was probed with anti-EPO antibody as described in Table 8, washed, and reprobed with 125-I-staph A protein. The filter was autoradiographed for two days. Native homogeneous EPO was described in Example 1, either before (lane B) or after iodination (lane C) were electrophoresed (see Figure 6). Markers used included sS methionine labelled, serum albumin (66,000 d) and ovalbumin (45,000 d).

Example 9: Construction of RIK1-4

The Bam HI-PvuII fragment from the plasmid PSV2DHFR (Subramani et al., Mol. Cell. Biol. 1:854-864 (1981)) containing the SV40 early region promoter adjacent to the mouse dihydrofolate reductase (DHFR) gene, an SV40 enhancer, the small t antigen intron, and the SV40 polyadenylation sequence was isolated (fragment A). The remaining fragments were obtained from the vector p91023(A) (supra) as follows: p91023(A) was digested with Pst I at the single Pst I site near to the adenovirus promoter to linearize the plasmid and either ligated to synthetic Pst I to EcoRI converters and recircularized (creating the sites Pst I - EcoRI - Pst I at the original Pst I site; 91023(B)) or treated with the large fragment of DNA polymerase I to destroy the Pst I sites and ligated to a synthetic EcoRI linker and recircularized (creating an EcoRI site at the original Pst I site; 91023(B)). Each of the two resulting plasmids 91023(B) and 91023(B) were digested with Xba and EcoRI to produce two fragments (F and G). By joining fragment F from p91023(B) and fragment G from p91023(B) and fragment G from p91023(B) and fragment F from p91023(B) two new plasmids were created which contained either an EcoRI - Pst I site or a Pst I - EcoRI site at the original Pst I site. The plasmid containing the Pst I - EcoRI site where the Pst I site is closest to the adenovirus major late promoter was termed p91023(C).

The vector p91023(C) was digested with XhoI to completion and the resulting linearized DNA with sticky ends was bluntly by an end filling reaction with the large fragment of E. coli DNA polymerase I. To this DNA was ligated a 340 bp Hind III EcoRI fragment containing the SV40 enhancer prepared as follows:

The Hind III - Pvu II fragment from SV40 which contains the SV40 origin or replication and the enhancer was inserted into the plasmid c lac (Little et al., Mol. Biol. Med. 1:473-488 (1983)). The c lac vector was prepared by digesting c lac DNA with BamHI, filling in the sticky end with the large fragment of DNA polymerase I and digesting the DNA with Hind III. The resulting plasmid (c SVHPac) regenerated the

BamHI site by ligation to the Pvu II blunt end. The EcoRI - Hind III fragment was prepared from c SVHPlac and ligated to the EcoRI - Hind III fragment of pSV0d (Mellon et al., supra) which contained the plasmid origin of replication and the resulting plasmid pSVHPOd was selected. The 340 bp EcoRI - Hind III fragment of pSVHPOd containing the SV40 origin/antigen was then prepared, blunt-ended at both ends with the large fragment of DNA polymerase I, and ligated to the XhoI digested, blunt-ended p91023(c) vector described above. The resulting plasmid (p91023(c)/XhoI/blunt plus EcoRI/Hind III/blunt SV40 origin plus enhancer) in which the orientation of the Hind III - EcoRI fragment was such that the BamHI site within that fragment was nearest to the VA gene was termed pES105. The plasmid pES105 was digested with Bam HI and PvuII and also with PvuII alone and the BamHI - PvuII fragment containing the adenovirus major late promoter (fragment B) and the PvuII fragment containing the plasmid during resistance gene (tetacycline resistance) and other sequences (fragment C) were isolated. Fragments A, B and C were ligated and the resulting plasmid shown in Figure 7 was isolated and termed RK1-4. Plasmid RK1-4 has been deposited with the American Type Culture Collection, Rockville, Maryland, where it is available under Accession Number ATCC 38940.

Example 10: Expression of EPO in CHO cells-Method I

DNA (20 ug) from the plasmid pPTFL13 described above (Example 8) was digested with the restriction endonuclease Cla I to linearize the plasmid and was ligated to Cla I-digested DNA from the plasmid pAd26SVP(A) 1 (2 ug) which contains an intact dihydrofolate reductase (DHFR) gene driven by an adenovirus major late promoter (Kaufman and Sharp, Mol. and Cell Biol. 2:1304-1318 (1982)). This ligated DNA was used to transfect DHFR-negative CHO cells (DUKX-BII, Chasin L.A. and Urlaub G. (1980) PNAS 77 4218-4220) and following growth for two days, cells which incorporated at least one DHFR gene were selected in alpha media lacking nucleotides and supplemented with 10% dialyzed fetal bovine serum. Following growth for two weeks in selective media, colonies were removed from the original plates, pooled into groups of 10-100 colonies per pool, replated and grown to confluence in alpha media lacking nucleotides. The supernatant media from the pools grown prior to methotrexate selection were assayed for EPO by RIA. Pools which showed positive EPO production were grown in the presence of methotrexate (0.02 uM) and then subcloned and reassayed. EPO Clon 4 4.02-7, a single subclone from the EPO Clon 4 4.02 pool, releases 480 ng/ml EPO into media containing 0.02 uM MTX (Table 10). EPO Clon 4 4.02-7 is the cell line of choice for EPO production and has been deposited with the American Type Culture Collection as Accession Number ATCC CRL6895. Currently, this clone is being subjected to stepwise selection in increasing concentrations of MTX, and will presumably yield cells which produce even higher levels of EPO. For pools which were negative by RIA, methotrexate resistant colonies obtained from the counterpart cultures which were grown in the presence of methotrexate (0.02 uM) were again reassayed in pools for EPO by RIA. Those cultures which were not positive were subcloned and subjected to growth in further increasing concentrations of methotrexate.

Stepwise methotrexate (MTX) selection was achieved by repeated cycles of culturing the cells in the presence of increasing concentrations of methotrexate and selecting for survivors. At each round, EPO was measured in the culture supernatant by RIA and by in vitro biological activity. The levels of methotrexate used in each stepwise amplification were 0.02 uM, 0.1 uM, and .5 uM. As shown in Table 10 after 1 round of selection in .02 uM MTX significant levels of EPO were being released into the culture media.

TABLE 10

Sample	Level of EPO Released into the Media		
	Assay	Alpha medium harvest	0.02 uM methotrexate in alpha medium harvest
4.4 Pool	RIA	17 ng/ml	50 ng/ml
4.4 Single Colony Clone (02-7)	RIA	-	480 mg/ml

Example 11: Expression of EPO in CHO cells - Method II

DNA from the clone lambda HEPOL13 was digested with EcoRI and the small RI fragment containing the EPO gene was subcloned into the EcoRI site of the plasmid RK1-4 (See Example 10). This DNA (RKFL13) was then used to transfect the DHFR-negative CHO cells directly (without digestion) and the selection and amplification was carried out as described in Example 10 above.

The RKFL13 DNA was also inserted into CHO cells by protoplast fusion and microinjection. Plasmid RKFL13 has been deposited and is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 38988.

TABLE 11

Sample	Level of EPO Released into the Media		
	Assay	alpha medium harvest	0.02uM methotrexate in alpha medium harvest
Colony Pool A	RIA	3 ng/ml	42 ng/ml (pool) 150 ng/ml (clone) 1.5 U/ml
Single Colony clone(02C-2)	RIA 3H-Thy	-	80 ng/ml 5.9 U/ml
Microinjected pool (DEPO-1)	RIA 3H-Thy	60 ng/ml 1.8 U/ml	160 ng/ml -

The preferred single colony clone has been deposited and is available from the American Type Culture Collection, Rockville, Maryland under Accession Number ATCC CRL6895.

Example 12: Expression of EPO Genomic Clone in COS-1 Cells

The vector used for expression of the EPO genomic clone is pSV0d (Mellon et al., supra). DNA from pSV0d was digested to completion with Hind III and blunted with the large fragment of DNA polymerase I. The EPO genomic clone lambda-HPO3 was digested to completion with EcoRI and Hind III and the 4.0 kb fragment containing the EPO gene was isolated and blunted as above. The nucleotide sequence of this fragment from the Hind III site to a region just beyond the polyadenylation signal is shown in Figure 4 and Table 4. The EPO gene fragment was inserted into the pSV0d plasmid fragment and correctly constructed recombinants in both orientations were isolated and verified. The plasmid C22-1 has the EPO gene in orientation "a" (i.e. with the 5' end of EPO nearest to the SV40 origin) and the plasmid C21-3 is in the opposite orientation (orientation "b").

The plasmids C21-3 and C22-1 were transfected into COS-1 cells as described in Example 7 and media was harvested and assayed for immunologically reactive EPO. Approximately 31 ng/ml of EPO was detected in the culture supernatant from C22-1 and 18-31 ng/ml from C21-3.

Genomic clones HEP01, HEP02, and HEP08 can be inserted into COS cells for expression in a similar manner.

Example 13: Expression in C127 and in 3T3 Cells Construction of pBPVEPO

A plasmid containing the EPO cDNA sequence under the transcriptional control of a mouse metallothionein promoter and linked to the complete bovine papilloma virus DNA was prepared as follows:

The plasmid pSP65 was purchased from Promega Biotec. This plasmid was digested to completion with EcoRI and the 1340 bp EcoRI fragment from lambda-HEPOFL13 was inserted by DNA ligase. A resulting plasmid in which the 5' end of the EPO gene was nearest to the SP6 promoter (as determined by BglI and Hind III digestion) was termed pEPO48F. In this orientation, the BamHI site in the pSP65 polylinker is directly adjacent to the 5' end of the EPO gene.

pMMTneo BPV

The plasmid pBPV-mMTneo (342-12) (Law et al., Mol. and Cell Biol. 3:2110-2115 (1983)), illustrated in Figure 6, was digested to completion with BamHI to produce two fragments - a large fragment -88b in length containing the BPV genome and a smaller fragment, -6.5 kb in length, containing the pML2 origin of replication and ampicillin resistance gene, the metallothionein promoter, the neomycin resistance gene, and the SV40 polyadenylation signal. The digested DNA was reconstituted by DNA ligase and plasmids which contained only the 6.8 kb fragment were identified by EcoRI and BamHI restrictions endonuclease digestion. One such plasmid was termed pmmTneo BPV.

pEPO15a

pMMTneo BPV was digested to completion with BglII. pEPO48F was digested to completion with BamHI and BglII and the approximately 700 bp fragment containing the entire EPO coding region was prepared by gel isolation. The BglII digested pMMTneo BPV and the 700 bp BamHI/BglII EPO fragment were ligated and resulting plasmids containing the EPO cDNA were identified by colony hybridization with an oligonucleotide d(GGTTCATCTGTCCTCCCTGTCC) probe which is specific for the EPO gene. Of the plasmids which were positive by hybridization analysis, one (pEPO15a) which had the EPO cDNA in the orientation such that the 5' end of the EPO cDNA was nearest the metallothionein promoter was identified by digestion with EcoRI and KpnI.

pBPV-EPO

The plasmid pEPO15a was digested to completion with BamHI to linearize the plasmid. The plasmid pBPV-MMTneo(342-12) was also digested to completion with BamHI to produce two fragments of 6.5 and 8b. The 8b fragment which contained the entire Bovine Papilloma Virus genome, was gel isolated. pEPO15a/BamHI and the 8b BamHI fragment were ligated together and a plasmid (pBPV-EPO) which contained the BPV fragment were identified by colony hybridization using an oligonucleotide probe d(PCCACACCCGGTACACA-OH) which is specific for the BPV genome. Digestion of pBPV-EPO DNA with Hind III indicated that the direction of transcription of the BPV genome was the same as the direction of transcription of the metallothionein promoter (as in pBPV-MMTneo(342-12) see Figure 6). The plasmid pBPV-MMTneo(342-12) is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 37224.

Expression

The following methods were used to express EPO.

Method I

DNA pBPV-EPO was prepared and approximately 25 ug was used to transfect -1×10^6 C127 (Lowy et al., J. Virol. 28:281-88 (1978)) CHO cells using standard calcium phosphate precipitation techniques (Graham et al., Virology, 52:459-47 (1973)). Five hrs. after transfection, the transfection media was removed, the cells were glycerol shocked, washed, and fresh α -medium containing 10% fetal bovine serum was added. Forty-eight hrs. later, the cells were trypsinized and split at a ratio of 1:10 in DME medium containing 500 ug/ml G418 (Southern et al., Mol. Appl. Genet. 1:327-41 (1982)) and the cells were incubated for two-three weeks. G418 resistant colonies were then isolated individually into microtiter wells and grown

until sub-confluent in the presence of G418. The cells were then washed, fresh media containing 10% fetal bovine serum was added and the media was harvested 24 hours later. The conditioned media was tested and shown to be positive for EPO by radioimmunoassay and by in vitro biological assay.

Method II

C127 or 3T3 cells were cotransfected with 25ug of pBPV-EPO and 2ug of pSV2neo (Southern et al., supra) as described in Method I. This is approximately at 10-fold molar excess of the pBPV-EPO. Following transfection, the procedure is the same as in Method I.

Method III

C127 cells were transfected with 30 ug of pBPV-EPO as described in Method I. Following transfection and splitting (1:10), fresh media was exchanged every three days. After approximately 2 weeks, foci of BPV transformed cells were apparent. Individual foci were picked separately into 1 cm wells of a microtiter plate, grown to a sub-confluent monolayer and assayed for EPO activity or antigenicity in the conditioned media.

Example 14: Expression in insect cells Construction of pIVEV EPOFL13

The plasmid vector pIVEV has been deposited and is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 39891. The vector was modified as follows:

pIVEVNI

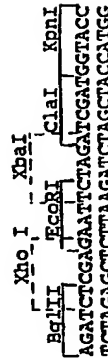
pIVEV was digested with EcoRI to linearize the plasmid, blunted using the large fragment of DNA polymerase I and a single NotI linker GGGCGCGCGC CGCGCGCGCGG was inserted by blunt end ligation. The resultant plasmid is termed pIVEVNI.

pIVEVSI

pIVEV was digested with SmaI to linearize the plasmid and a single SfiI linker GGGCCCCAGGGGGCCC CCGGGGGTCCCGCGGG was inserted by blunt end ligation. The resultant plasmid was termed pIVEVSI.

pIVEVSI8gKp

The plasmid pIVEVSI was digested with KpnI to linearize the plasmid and approximately 0 to 100 bp were removed from each end by digestion with the double-stranded exonuclease Bal 31. Any resulting ends which were not perfectly blunt were blunted using the large fragment of DNA polymerase I and the polylinker



was inserted by blunt end ligation. The polylinker was inserted in both orientations. A plasmid in which the

polylinker is oriented such that the BglII site within the polylinker is nearest to the polyhedron gene promoter is termed pIVEVSIgKqN1. A plasmid in which the KpnI site within the polylinker is nearest to the polyhedron gene promoter is termed pIVEVSIgKqBg. The number of base pairs which were deleted between the original KpnI site in pIVEVSI and the polyhedron promoter was not determined. The pIVEVSIgKqBg has been deposited with and is available from the American Type Culture Collection, Rockville, Maryland under Accession No. ATCC 39888.

pIVEVSIgKqN1

pIVEVSI was digested to completion with KpnI and PstI to produce two fragments. The larger fragment, which contained the plasmid origin of replication and the 3' end of the polyhedron gene was prepared by gel isolation (fragment A). pIVEVSIgKqBg was digested to completion with pstI and KpnI to produce two fragments and the smaller fragment, which contained the polyhedron gene promoter and the polylinker was prepared by gel isolations (fragment B). Fragment A and B were then joined by DNA ligase to form the new plasmid pIVEVSIgKqN1 which contains a partially deleted polyhedron gene into which a polylinker has been inserted and also contains a NdeI site (replacing the destroyed EcoRI site) and a SfiI site which flank the polyhedron gene region.

pIVEPO

pIVEVSI BGKpN1 was digested to completion with EcoRI to linearize the plasmid and the 1340 bp EcoRI fragment from lambdaB-HEPOFL13 was inserted. Plasmids containing the EPO gene in the orientation such that the 5' end of the EPO gene is nearest the polyhedron promoter and the 3' end of the polyhedron gene were identified by digestion with BglII. One of these plasmids in the orientation described above was designated pIVEPO.

Expression of EPO in Insect Cells

Large amounts of the pIVEPO plasmid were made by transforming the *E. coli* strain JM101-ql. The plasmid DNA was isolated by cleared lysate technique (Maniatis and Fritsch, Cold Spring Harbor Manual) and further purified by CsCl centrifugation. Wild-type Autographa californica polyhedrosis virus (AcNPV) strain L-1 DNA was prepared by phenol extraction of virus particles and subsequent CsCl purification of the viral DNA.

These two DNAs were then cotransfected into *Spodoptera frugiperda* cells (PLB-SF-21 (Vaughn et al., In Vitro Vol. B, pp. 213-17 (1977)) using the calcium phosphate transfection procedure (Potter and Miller, 1977). For each plate of cells being cotransfected, 1 µg of wild-type AcNPV DNA and 10 µg of pIVEPO were used. The plates were incubated at 27°C for 5 days. The supernatant was then harvested and EPO expression in the supernatant was confirmed by radioimmunoassay and by *in vitro* biological assay.

Example 15: Purification of EPO

COS-cell conditioned media (121) with EPO concentrations up to 200 µg/litre was concentrated to 800 ml using 10,000 molecular weight cutoff ultrafiltration membranes, such as a Millipore Pellicon fitted with 5 sq. ft. of membrane. Assays were performed by RIA as described in Example 6. The concentrate from the ultrafiltration was dialyzed against 4 ml of 10 mM sodium phosphate buffered at pH7.0. The concentrated and dialyzed condition media contained 2.5 mg of EPO in 380 mg of total protein. The EPO solution was further concentrated to 180 ml and the precipitated proteins were removed by centrifugation at 110,000 xg for 30 minutes.

The supernatant which contained EPO (2.0 mg) was adjusted to pH5.5 with 50% acetic acid, allowed to stir at 4°C for 30 minutes and the precipitate removed by centrifugation at 13,000 xg for 30 minutes.

Carbonylmethyl Sepharose Chromatography

The supernatant from the centrifugation (20 ml) containing 200 µg of EPO (24 mg total protein) was applied to a column packed with CM-Sepharose (20 ml) equilibrated in 10 mM sodium acetate pH5.5, washed with 40 ml of the same buffer. EPO which bound to the CM-Sepharose was eluted with a 100 ml gradient of NaCl (0-1) in 10 mM sodium phosphate pH5.5. The fractions containing EPO (total of 50 µg in 2 mg of total proteins) were pooled and concentrated to 2 ml using Amicon YM10 ultrafiltration membrane.

Reverse phase-HPLC

The concentrated fractions from CM-Sepharose containing the EPO was further purified by reverse phase-HPLC using Vydac C-4 column. The EPO was applied onto the column equilibrated in 10% solvent B (Solvent A was 0.1% CF₃CO₂H in water, solvent B was 0.1% CF₃CO₂H in CF₃CO₂H) at flow rate of 1 ml/min. The column was washed with 10% B for 10 minutes and the EPO was eluted with linear gradient of B (10-70% in 80 minutes). The fractions containing EPO were pooled (~40 µg of EPO in 120 µg of total proteins) and lyophilized. The lyophilized EPO was reconstituted in 0.1 M Tris-HCl at pH7.5 containing 0.15 M NaCl and rechromatographed on the reverse phase HPLC. The fractions containing the EPO were pooled and analyzed by SDS-polyacrylamide (10%) gel electrophoresis (Lameli, U.K., Nature). The pooled fractions of EPO contained 15.5 µg of EPO in 25 µg of total protein.

The invention has been described in detail, including the preferred embodiments thereof. It will, however, be appreciated that those skilled artisans may make modifications and improvements upon consideration of the specification and drawings set forth herein, without departing from the spirit and scope of this invention as set forth in the appended claims.

REFERENCES

- 1) Jacobson, L. O., Goldwasser, E., Fried, W., and Plzak, L. F., *Trans. Assoc. Am. Physicians* TO-305-317 (1957).
- 2) Krantz, S. B. and Jacobson, L. O. Chicago: University of Chicago Press 1970, pp. 29-31.
- 3) Hammond, D. and Winnick, S. Ann. N.Y. Acad. Sci. 230:216-227 (1974).
- 4) Sherwood, J. B. and Goldwasser, E., *Endocrinology* 103:868-870 (1978).
- 5) Fried, W. *Blood* 40:671-677 (1972).
- 6) Fisher, J. J. Lab. and Clin. Med. 83:695-698 (1979).
- 7) Naughton, B. A., Kaplan, S. M., Roy, M., Burdowski, A. J., Gordon, A. S., and Pileri, S. J. *Science* 195:301-302.
- 8) Lucarelli, G. P., Howard, D., and Shohman, F., Jr. *J. Clin. Invest.* 43:2195-2203 (1964).
- 9) Zanjanli, E. D., Poester, J., Burlington, H., Mann, L. T., and Wasserman, L. R. *J. Lab. Clin. Med.* 88:640-644 (1977).
- 10) Krantz, S. B., Gallien-Larigue, O., and Goldwasser, E. *J. Biol. Chem.* 238:4085-4090 (1963).
- 11) Dunn, C. D., Jarvis, J. H. and Greenman, J. M. *Exp. Hematol.* 3:65-78 (1975).
- 12) Krystal, G. *Exp. Hematol.* 11:649-660 (1983).
- 13) Iscove, N.N., and Guilbert, L.J., M.J. Murphy, Jr. (Ed.) New York: Springer-Verlag, pp. 3-7 (1978).
- 14) Goldwasser, E., *ICN UCL Symposium*, Control of Cellular Division and Development, A. R. Liss, Inc., pp. 487-494 (1981).
- 15) Ching, M. J. and Gode, D. W. *Nature* 277:177-181 (1979).
- 16) Metcalf, D., Johnson, G. R., and Burgess, A. W. *Blood* 55:139- (1980).
- 17) Krane, N. Henry Ford Hosp. Med. J. 31:177-181 (1983).
- 18) Eschbach, J., Madenovic, J., Garcia, J., Wahl, P., and Adamson, J. J. *Clin. Invest.* 74:494-441 (1984).
- 19) Anagnostou, A., Barone, J., Vedo, A., and Fried, W. Br. J. Hematol. 57:85-91 (1977).
- 20) Miyake, T., Kung, C., and Goldwasser, E. *J. Biol. Chem.* 252:5558-5564 (1977).
- 21) Yanagawa, S., Hirada, K., Ohnoda, H., Sasaki, R., Chiba, H., Veda, M., and Goto, M. *J. Biol. Chem.* 259:2707-2710 (1984).
- 22) Lamm, R. M., Fritsch, E. F., Parker, R. C., Blake, G., and Maniatis, T. *Cell* 15:1157- (1978).
- 23) Sanger, F., Nicklen, S., and Coulson, A. R. *Proc. Natl. Acad. Sci., U.S.A.* 74:5463- (1977).
- 24) Zanjanli, E.D., Accensio, J.L., McGlave, P.B., Barisade, M., and Ash, R. C. *J. Clin. Invest.* 87:1183- (1981).
- 25) Toole, J.J., Knopf, J.L., Wozney, J.M., Soltzman, L.A., Buecker, J. L., Pittman, D. D., Kaufman, R. J.,

- Brown, E., Shemakier, C., Orr, E. C., Amphlett, G. W., Foster, W. B., Coe, M. L., Knutson, G. J., Fass, D. N., and Hewick, R. M. *Nature* in Press
- 26) Goldwasser, E. *Blood Suppl.* 7, 58, xli (abstr) (1981)
- 27) Sue, J. M. and Sytkowski, A. J. *Proc. Natl. Acad. Sci. U.S.A.* 80:3851-3855 (1983)
- 28) Bensch, N. and Goldwasser, E. *In Vitro Aspects of Erythropoiesis*, M. J. Murphy (Ed.), New York: Springer-Verlag (1978)
- 30) Coles, P. M. and Bingham, D. R. *Nature* 181:1085- (1981)
- 31) Goldwasser, E. and Gross, M. *Methods in Enzymol.* 37:108-121 (1975)
- 32) Nabeshima, Y., Fujii-Kuriyama, Y., Muramatsu, M., and Ogata, K. *Nature* 308:333-338 (1984)
- 33) Young, R. A., Hagencich, O., and Schibler, U. *Cell* 23:451-558 (1981)
- 34) Medford, R. M., Nguyen, H. T., Destree, A. T., Summers, E. and Nadal-Ginard, B. *Cell* 38:409-421 (1984)
- 35) Zih, E. B. *Nature* 287:481-488 (1980)
- 36) Early, P. *Cell* 20:313-319 (1980)
- 37) Sytkowski, A. *Bio. Biop. Res. Comm.* 98:143-148 (1980)
- 38) Murphy, M. and Miyake, T. *Acta Haematol. Jpn.* 48:1380-1398 (1983)
- 39) Wagh, P. V. and Bahl, O. P. *CRC Critical Reviews in Biochemistry* 307-377 (1981)
- 40) Wang, F. F., Kung, C. K.-H. and Goldwasser, E. *Fed. Proc. Fed. Am. Soc. Exp. Biol.* 42:1872 (abstr) (1983)
- 41) Lowy, P., Kieghley, G. and Borsook, H. *Nature* 185:102-103 (1980)
- 42) VanLent, L. and Ashwell, G. J. *Biol. Chem.* 247:4833-4840 (1972)
- 43) Lee-Huang, S. *Proc. Natl. Acad. Sci. U.S.A.* 81:2708-2712 (1984)
- 44) Fyhrquist, F., Rosenlof, K., Gronhagen-Riska, C., Hordling, L. and Tikkanen, I. *Nature* 308:549-562 (1984)
- 45) Ohkubo, H., Kageyama, R., Vihara, M., Hirose, T., Inayama, S., and Nakanishi, S. *Proc. Natl. Acad. Sci. U.S.A.* 80:2196-2200 (1983)
- 46) Suggs, S.V., Wallace, R. B., Hirose, T., Kawashima, E. H. and Itakura, K. *Proc. Natl. Acad. Sci. U.S.A.* 78:6813-6817 (1981)
- 47) Woo, S. L. C., Dugalczyk, A., Tsai, M. -J., Lai, E. C., Catherall, J. F. and O'Malley, B. W. *Proc. Natl. Acad. Sci. U.S.A.* 75:3888- (1978)
- 48) Mischak, H. B. and VonHippel, P. H. *Proc. Natl. Acad. Sci. U.S.A.* 70:288-302 (1973)
- 49) Orosz, J. M. and Weimn, J. G. *Biopolymers* 16:1183-1188 (1977)
- 50) Anderson, S. and Kingston, I. B. *Proc. Natl. Acad. Sci. U.S.A.* 80:6838-6842 (1983)
- 51) Ullrich, A., Coussens, L., Hayflick, J. S., Dull, T. J., Gray, A., Tam, A. W., Lee, J., Yarden, Y., Libermann, T. A., Schlessinger, J., Downward, J., Mayes, E. L. V., Whittle, H., Waterfield, M.D. and Seeburg, P. H. *Nature* 309:419-425 (1984)
- 52) Fisher, J. *Proc. Soc. Exptl. Biol. and Med.* 173:288-305 (1983)
- 53) Kozak, M. *Nuc. Acid Res.* 12:857-872 (1984)
- 54) Benton, W.D. and Davis, R.W. *Science* 188:180-182 (1977)
- 55) Sherwood, J.B. and Goldwasser, E. *Blood* 54:885-893 (1979)
- 56) Derman, E., Krauter, K., Walling, L., Weinberger, C., Ray, M., and Darnell, J. T., *Cell* 23:731- (1981)
- 57) Gluzman, Y., *Cell* 23:175-182 (1981)
- 58) Hewick, R. M., Hunkapiller, M. E., Hood, L. E., and Dreyer, W. J. *J. Biol. Chem.* 258:7890-7897 (1981)
- 59) Towbin, H., Staehelin, T., and Gordon, J. *Proc. Natl. Acad. Sci.* 78:4380- (1978)
- 60) Carnot, P., Defandre, C. C. *R. Acad. Sci. Paris* 143:432- (1980)

Claims

1. Recombinant DNA plasmid vector containing cDNA encoding human EPO of clone lambda HEPOFL13 (ATCC 40153).
2. A mammalian cell transformed with the transfer vector of claim 1.
3. The cell of claim 2, wherein said mammalian cell is a 3T3, C127 or CHO cell.
4. A mammalian cell containing a plasmid which contains the entire bovine papilloma virus DNA and the cDNA sequence of Table 3 coding for human EPO.
5. The cell of claim 4, wherein said cell is a C127 or 3T3 cell.
6. The cell of claim 5, wherein said EPO DNA is under transcriptional control of a mouse metallothionein

7. The cell of claim 5, wherein said cell contains a plasmid comprising DNA from pdBVP-MMTneo(342-12) (ATCC 37224).
8. Recombinant human erythropoietin characterized by the presence of O-linked glycosylation, obtainable by the steps of
 - (a) culturing in a suitable medium CHO cells containing a DNA sequence encoding human erythropoietin said DNA sequence operatively linked to an expression control sequence and
 - (b) recovering and separating the EPO from the cells and the medium.
9. Recombinant human erythropoietin according to claim 8, characterized by a glycosylation pattern comprising fucose.
10. Recombinant human erythropoietin according to claim 8, characterized by a glycosylation pattern comprising relative molar levels of hexoses to N-acetylglucosamine (Nacglc) of 1.4 : 1, specifically galactose : Nacglc = 0.9 : 1 and mannose : Nacglc = 0.5 : 1.
11. Recombinant human erythropoietin according to claim 9 or 10, characterized by the presence of N-acetylglucosamine.

ADULT LIVER
FETAL LIVER



FIG. 1

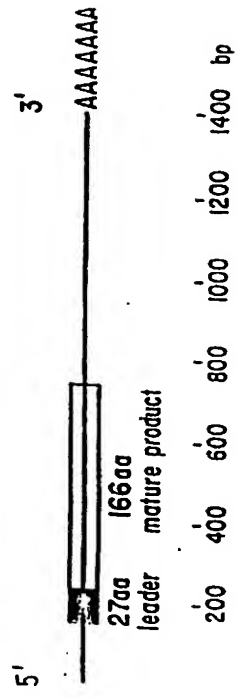


FIG. 2

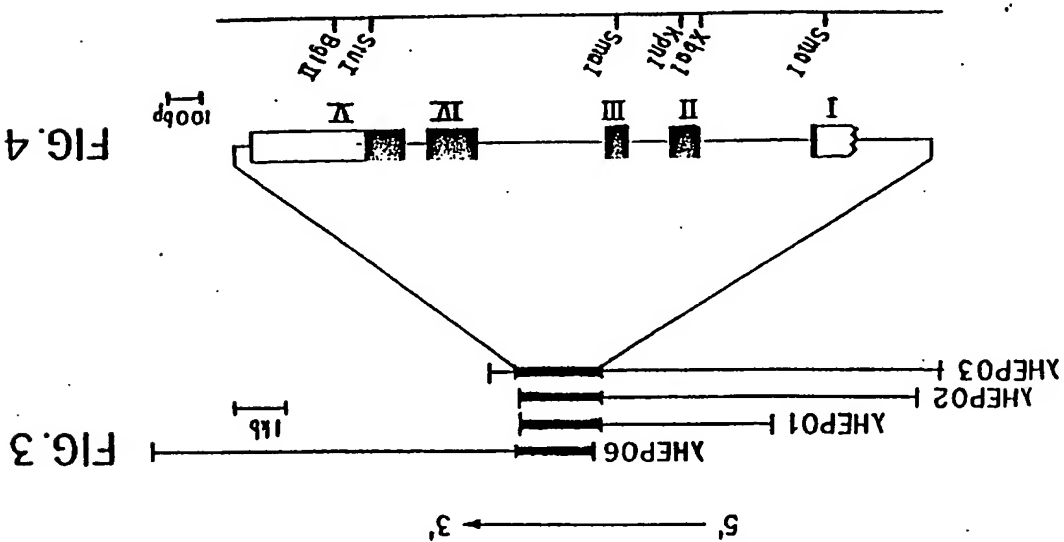


FIG. 4

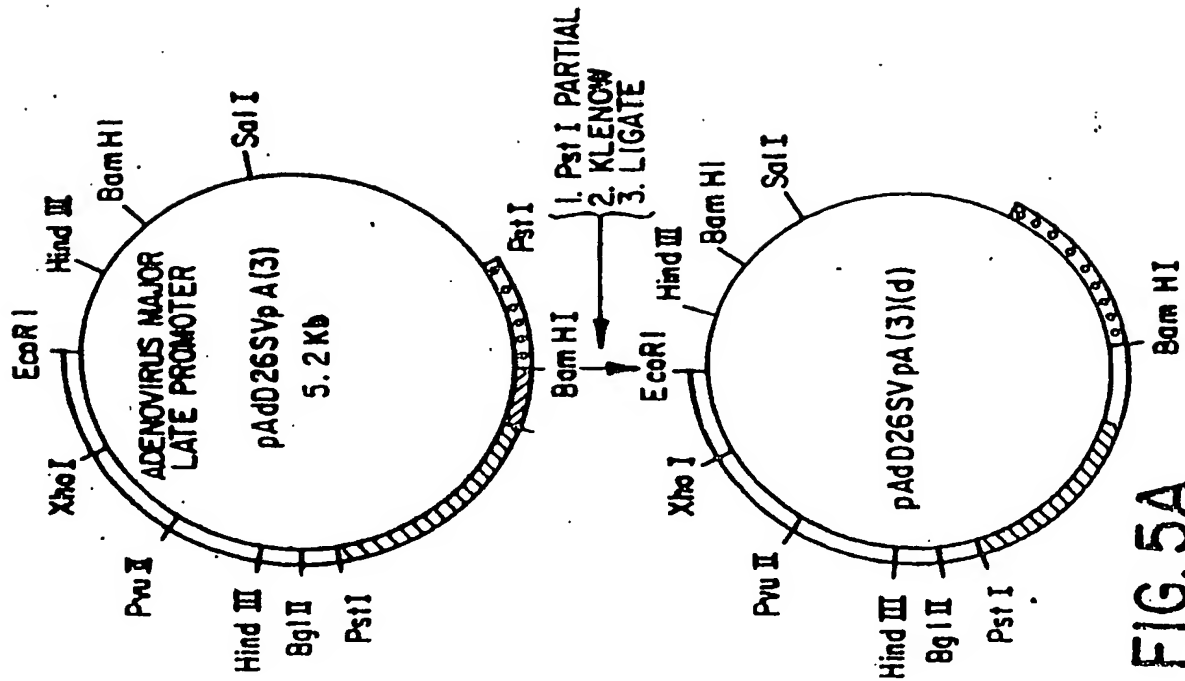


FIG. 5A

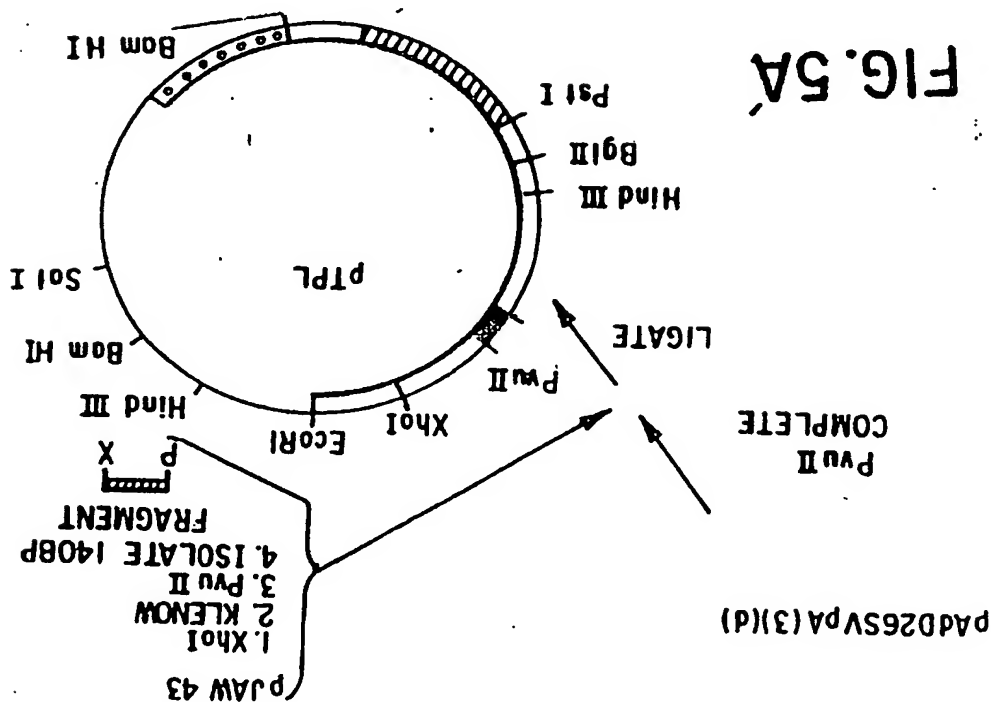
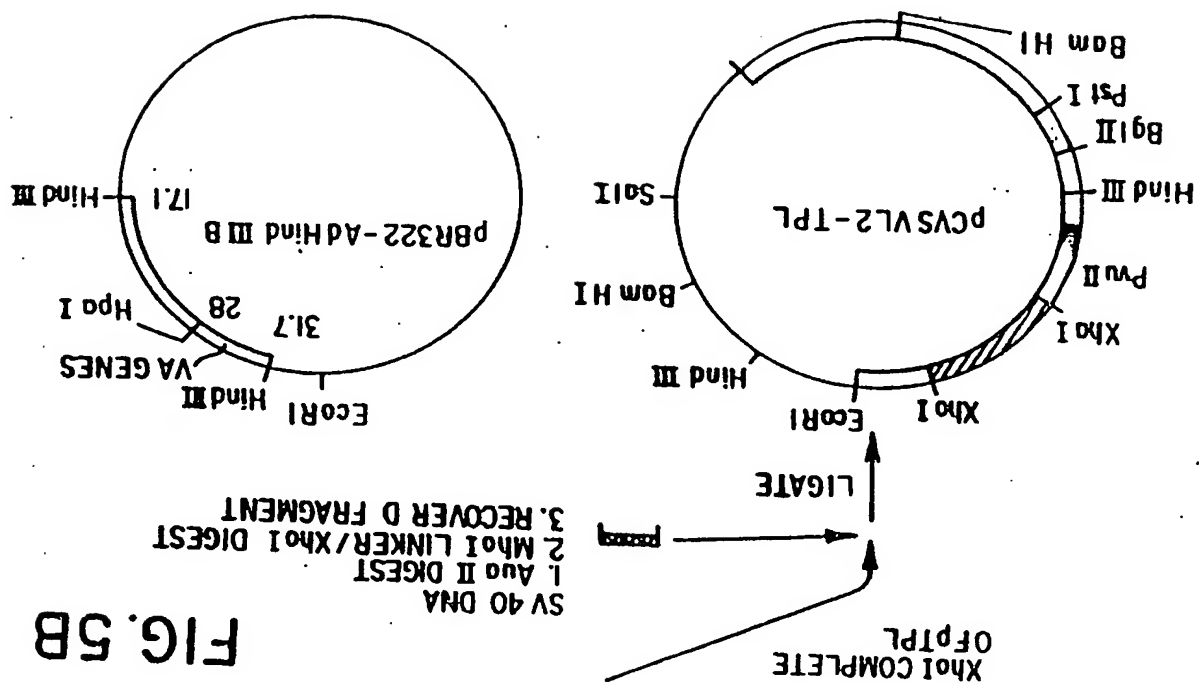


FIG. 5C

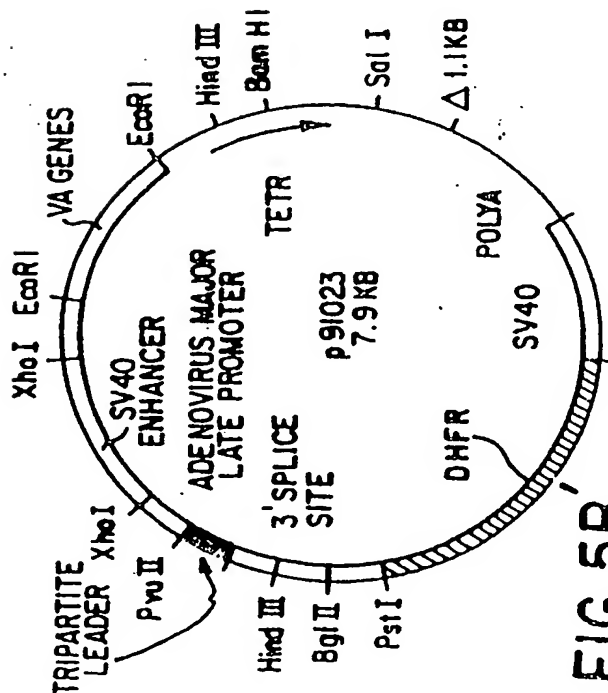
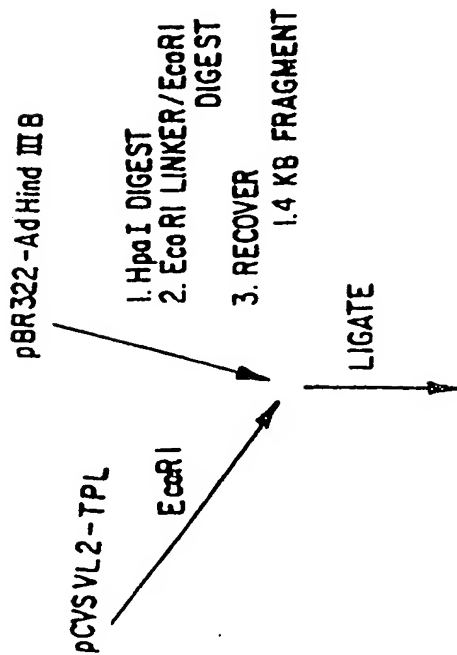
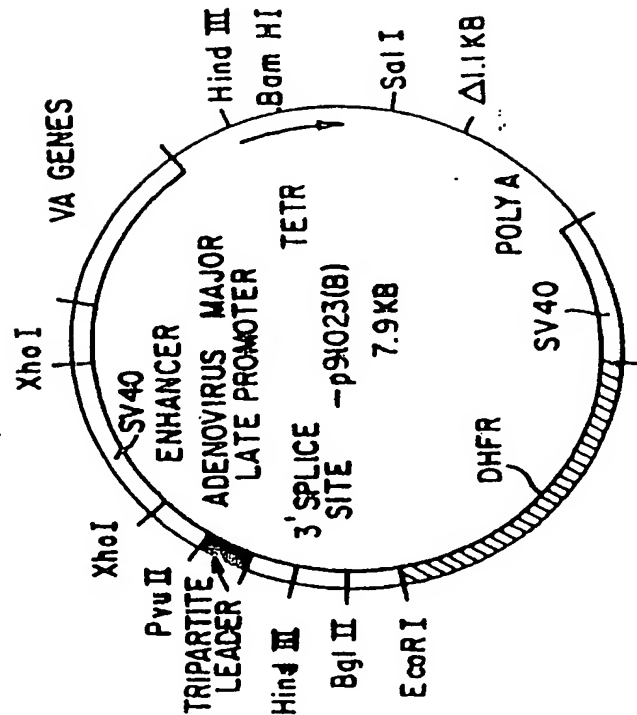
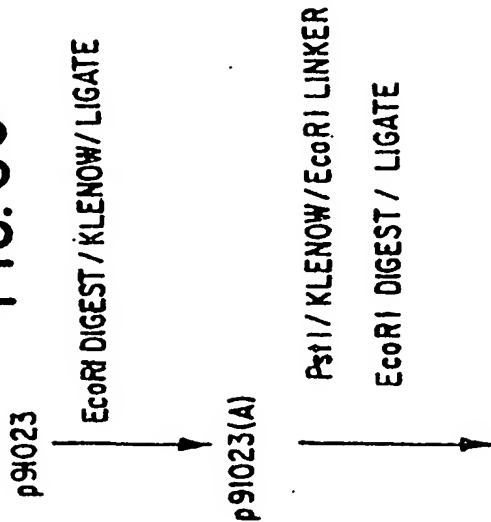


FIG. 5B

FIG. 6

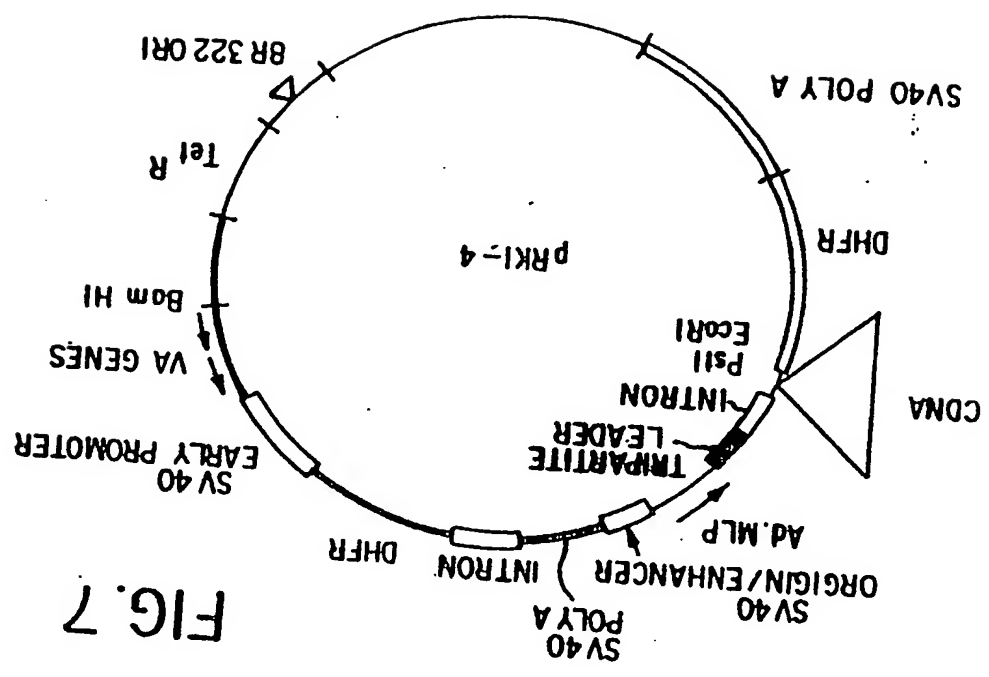
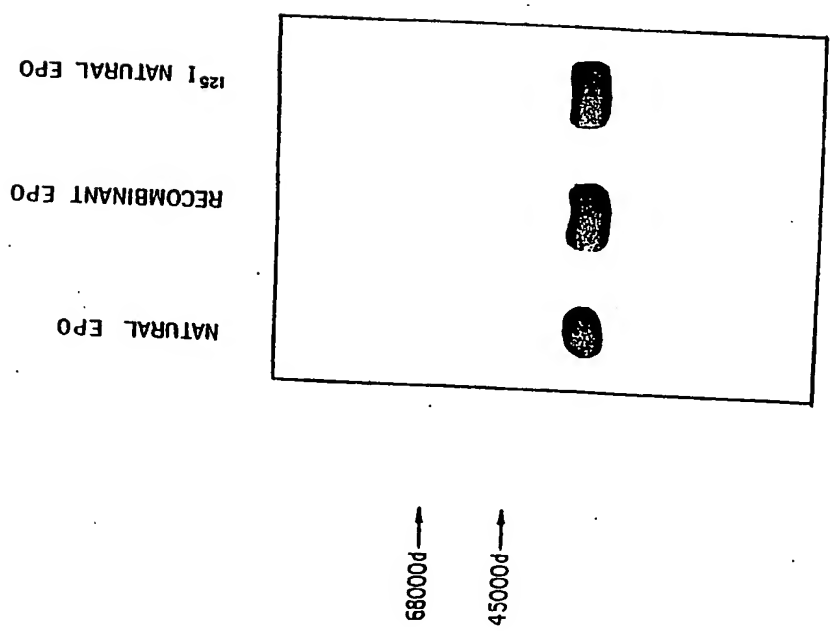
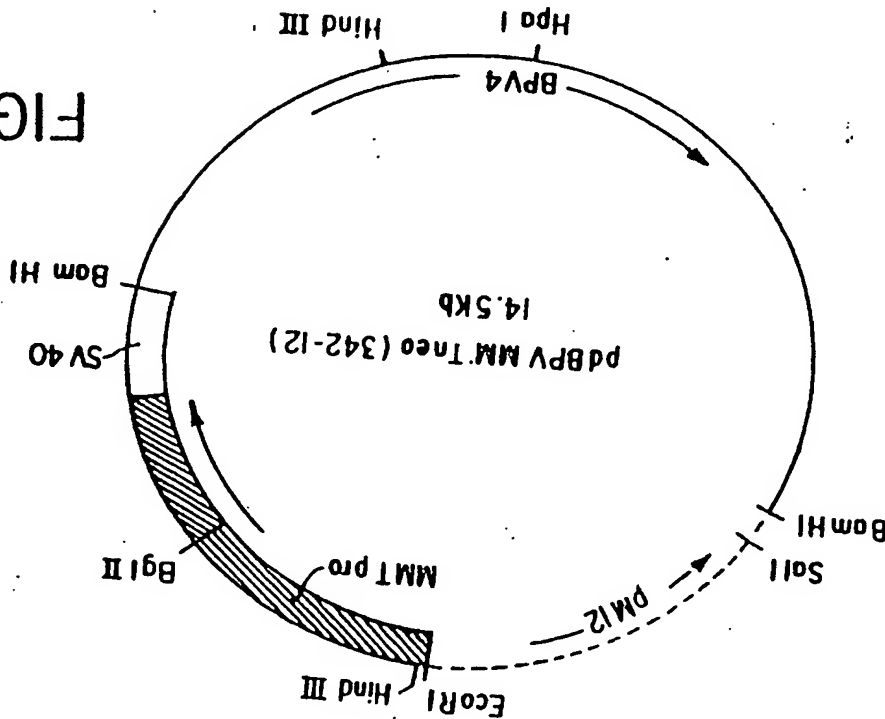


FIG. 7

FIG. 8



EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
X	PROC. NATL. ACAD. SCI. USA, vol. 81, May 1984, pages 2708-2712; S. LEE-HUANG: "Cloning and expression of human erythropoietin cDNA in Escherichia coli" * Whole document *	1,8	C 12 N 15/16 C 12 P 21/02 C 12 N 5/10 C 07 K 13/00
X	CHEMICAL ABSTRACTS, vol. 87, 1977, page 294, abstract no. 129775g, Columbus, Ohio, US; T. MIYAKE et al.: "Purification of human erythropoietin", & J. BIOL. CHEM. 1977, 252(15), 5558-64 * Whole abstract *	8	
P,X	NATURE, vol. 313, 28th February 1985, pages 806-810; K. JACOBSS et al.: "Isolation and characterization of genomic and cDNA clones of human erythropoietin" * Whole document *	1-3,8- 11	
P,X	WO-A-8 503 079 (NEW YORK UNIVERSITY) * Whole document *	1,8	TECHNICAL FIELD SEARCHED (Int. Cl.)
E	GB-A-2 171 304 (CHUGAI SEIYAKU K.K.) * Reference example 2 *	1-3,8- 11	C 12 N A 61 K C 07 K
E,L	CHEMICAL ABSTRACTS, vol. 105, no. 19, 10th November 1986, page 203, abstract no. 166280c, Columbus, Ohio, US; & JP-A-86 12 288 (GENETICS INSTITUTE) 20-01-1986	1-3,8- 11	
A	EXP. HEMATOL., vol. 12, 1984, page 357, abstract no. 1; F.K. LIN et al.: "Cloning and expression of monkey and human erythropoietin gene" -----		
The present search report has been drawn up for all claims			
THE HAGUE		Date of completion of the search 25-10-1990	Examiner DESCAMPS J.A.
CATEGORY OF CITED DOCUMENTS			T: theory or principle underlying the invention E: earlier patent document, in published or, or not published form D: document cited in the application L: document cited for other reasons A: technological background O: non-written disclosures P: information document
X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosures P: information document			A: number of the same patent family, corresponding document